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Original Article

Timing of Spring Surveys for Midcontinent Sandhill Cranes

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ABSTRACT The U.S. Fish and Wildlife Service has used spring aerial surveys to estimate numbers of migrating sandhill cranes (*Grus canadensis*) staging in the Platte River Valley of Nebraska, USA. Resulting estimates index the abundance of the midcontinent sandhill crane population and inform harvest management decisions. However, annual changes in the index have exceeded biologically plausible changes in population size (>50% of surveys between 1982 and 2013 indicate >±20% change), raising questions about nuisance variation due to factors such as migration chronology. We used locations of cranes marked with very-high-frequency transmitters to estimate migration chronology (i.e., proportions of cranes present within the Platte River Valley). We also used roadside surveys to determine the percentage of cranes staging at the Platte River Valley but outside of the survey area when surveys occur. During March 2001–2007, an average of 86% (71–94%; SD = 7%) of marked cranes were present along the Platte River during scheduled survey dates, and 0–11% of cranes that were present along the Platte River were not within the survey boundaries. Timing of the annual survey generally corresponded with presence of the greatest proportion of marked cranes and with least inter-annual variation; consequently, accuracy of estimates could not have been improved by surveying on different dates. Conducting the survey earlier would miss birds not yet arriving at the staging site; whereas, a later date would occur at a time when a larger portion of birds may have already departed the staging site and when a greater proportion of birds occurred outside of the surveyed area. Index values used to monitor midcontinent sandhill crane abundance vary annually, in part, due to annual variation in migration chronology and to spatial distribution of cranes in the Platte River Valley; therefore, managers should interpret survey results cautiously, with awareness of a continuing need to identify and understand components of variation.

KEY WORDS *Grus canadensis*, migration chronology, Nebraska, Platte River, population survey.

Wildlife monitoring programs that provide periodic estimates of abundance are especially useful for management of harvested populations and those in need of recovery (Caughley 1977, Conroy and Smith 1994, Stem et al. 2005). Objectives, logistic constraints, accuracy and precision of estimates, and costs of data collection are potential considerations when developing rigorous monitoring protocols. Given tradeoffs among these factors, many wildlife surveys are based on indices of population size rather than estimates of abundance (Caughley 1977, Lancia et al. 2005, Johnson 2008). To be useful to wildlife managers, population indices must be sensitive to changes in population size.

Determining relations between indices and absolute abundance requires knowledge of detection probabilities (Williams et al. 2002, Lancia et al. 2005). Population indices derived from sample surveys can be particularly useful for periodic monitoring of population abundance if detection probabilities are relatively predictable through space and time, are continually estimated as part of the monitoring program, or are sufficiently less variable than changes in abundance that the survey has been designed to detect (Pollock et al. 2002, Engeman 2005, Field et al. 2005). Variable detection rates reduce the utility of indices for tracking changes in abundance of populations. When interpreting population indices without knowledge of detection probabilities, managers must be cognizant that differences among surveys reflect variation in both abundance and detection (Johnson 2008).

The midcontinent population of sandhill cranes (*Grus canadensis*) breeds across a vast region extending from northeastern Russia to northwestern Minnesota and migrates each year to wintering areas from central Kansas, USA, to northern Mexico (Krapu et al. 2011). This is the

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largest sandhill crane population and has been hunted since the 1960s (Tacha et al. 1994). Each spring migration, midcontinent sandhill cranes congregate at the Central and North Platte Rivers in Nebraska, USA (U.S. Fish and Wildlife Service [USFWS 1981]) and, since 1957 the USFWS has conducted an annual spring aerial survey of migrating sandhill cranes in this region of south-central Nebraska (Lewis 1979). Weather permitting, surveys are conducted on the fourth Tuesday of March to coincide with presumed maximum abundance of cranes in the surveyed area (USFWS 1981). Crane numbers are estimated by counting cranes within sample transects and, since 1982, by comparing counts to aerial photographs and adjusting for under- or over-counting (Benning and Johnson 1987). Estimates are interpreted as an index of abundance for the midcontinent sandhill crane population; only a portion of the population is present at the Platte River because of annual variation in migration chronology. Survey results assist crane managers in setting annual harvest regulations (Central Flyway Webless Migratory Game Bird Technical Committee 2006).

Sandhill cranes are long-lived and do not breed until 3–4 years of age (Tacha et al. 1994). Furthermore, the midcontinent population typically comprises <15% young-of-the-year (Drewien et al. 1995) and estimated harvest has remained relatively stable during 1990–2012 (Kruse et al. 2013). These aspects of crane life history limit the potential for abrupt changes in population size, yet large annual fluctuations have been a hallmark of the population index (Tacha et al. 1994, Kruse et al. 2013). For example, between 1982 and 2013, only 20% of survey results indicated <±10% annual population change and 45% of surveys indicated <±20% change; average population decline was −25% (−1% to −56%) and average population increase was 39% (3–155%). Biologically implausible annual variation raises questions about validity and sensitivity of indices, which can only be addressed if components of variation are identified and understood. The crane survey protocol adopted in 1982 provided for estimation of sampling variation and observer bias (Benning and Johnson 1987). Although other sources of variation have not been quantified, variation in proportions of cranes that are present during surveys has also been a matter of long-standing concern (e.g., Tacha et al. 1994). Migrating cranes typically are present in the Platte River Valley from February to May; however, local abundance may change rapidly and only a portion of the midcontinent population typically is present at any given time (USFWS 1981). Moreover, observers have noted cranes foraging outside of the surveyed area during surveys. Although surveys are scheduled to coincide with peak crane numbers in the at the Platte River Valley, sensitivity of the index to changes in the midcontinent crane population hinges more on inter- and intra-annual variation in the proportion of cranes within the survey area. Crane managers recognize that these sources of variation influence reliability of the survey and have specifically identified modifying survey timing as a means to address potential biases in survey results (Central Flyway Webless Migratory Game Bird Technical Committee 2006). We thus used roadside transect surveys and locations of cranes marked with very-high-frequency (VHF) transmitters to estimate proportions of cranes that were staging at the Platte River and within the survey area and to evaluate the potential for improving sensitivity by modifying survey dates.

STUDY AREA

During migration, approximately 80–85% of midcontinent sandhill cranes stage in the Central Platte River Valley (CPRV), along the Big Bend Reach of the Platte River between Chapman and Lexington, Nebraska (Krapu et al. 2011). The remaining 15–20% stage in the North Platte River Valley (NPRV) between Sutherland and North Platte. The USFWS conducts crane surveys in both areas (Fig. 1). Radiomarked cranes generally used only one of the surveyed areas each year, and typically used the same area during successive years (Krapu et al. 2014). We limited our study of crane distribution to the primary spring staging region of the CPRV because the limited movement between the CPRV and NPRV would not be a major source of intra- and inter-annual variation in migration chronology.

The Platte River was a braided river with channels that were shallow, wide, and characterized by numerous emergent and submerged sandbars, which provided roosting sites for sandhill cranes (USFWS 1981). Dominant vegetation cover types within the CPRV were cropland, lowland grassland, upland grassland, riparian forest, and shrubland. During our study, croplands were planted primarily to corn and soybeans with limited amounts of wheat, sorghum, and alfalfa (Pearse et al. 2010). Cranes used river channels as nocturnal roost sites, nearby cornfields to feed, and meadows mainly to feed on invertebrates (Krapu et al. 1982, Reinecke and Krapu 1986).

METHODS

Capturing cranes along the Platte River during spring migration represents the most advantageous place to gather a representative sample, because this is the largest congregation of the population annually (Krapu et al. 2011, 2014). Attempting to obtain a representative sample of cranes at other times of the year would be extremely difficult because of their vast geographic distribution. Sandhill cranes can begin to arrive at the Platte River in early February and stay until the end of April (USFWS 1981). We chose to capture cranes from late February to early April because this was a time when the majority of cranes were present. Also, because cranes stay for an average of 20–25 days and most have arrived by early April (Krapu et al. 2014), most cranes that used the Platte River in any year would have been available for marking during annual capture periods.

Field Methods

During late February and early April 2000–2006, we used rocket-propelled nets and taxidermy-mounted decoys (Wheeler and Lewis 1972) to capture sandhill cranes at numerous sites between Chapman and Lexington, Nebraska (Krapu et al. 2011; Fig. 1). We selected adults for transmitter attachment, and typically marked 1–2 (max. of 4) cranes from each capture event. If marking multiple cranes, we chose

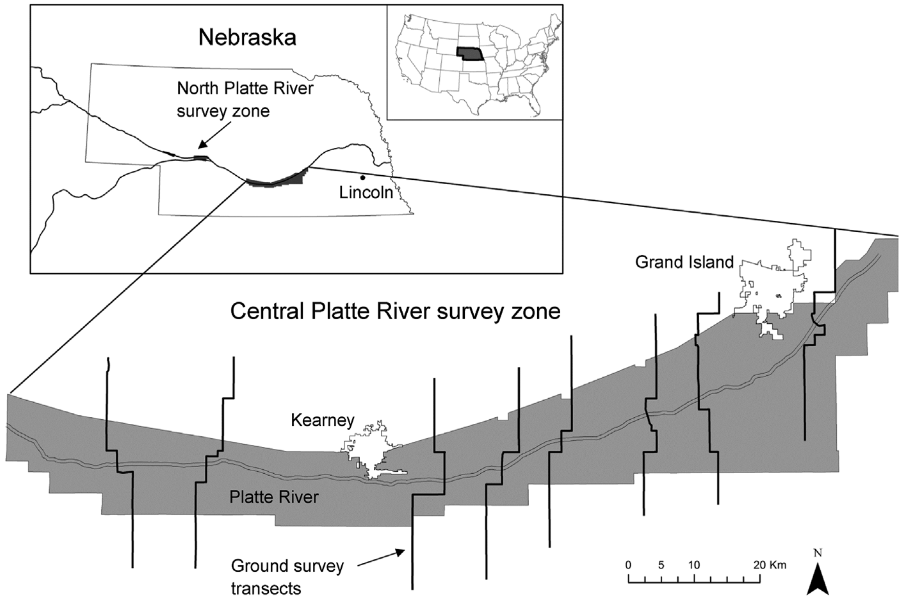

Figure 1. Areas within Nebraska, USA, where the U.S. Fish and Wildlife Service has conducted annual population surveys of spring-migrating sandhill cranes on the fourth Tuesday in March (gray area). We captured sandhill cranes during February–April 2000–2007 and conducted ground surveys along road transects in the Central Platte River Valley survey zone during 1998–2002 and 2009–2011.

birds from opposite ends of the net to limit the chance of sampling a mated pair. We used a 2-piece leg band (Haggie Engraving, Crumpton, MD) to attach a VHF transmitter (Advanced Telemetry Systems Inc., Isanti, MN) to the left leg of randomly selected cranes from each captured group. Inside diameters of leg bands were approximately equivalent to U.S. Geological Survey Bird Banding Laboratory band sizes 8 and 9, and transmitters mounted on leg bands weighed approximately 60–65 g. To extend battery life and permit tracking of individual cranes for several years, transmitters were programmed to cycle between active (mid-Feb–mid-Apr) and latent periods. To maintain potential group and family bonds, we released most captured birds (marked and unmarked) within 30 min (range = 15–60 min) of capture. Capture and marking procedures conformed to recommendations of the American Ornithologists' Union (1997) and followed the protocol contained in Study Plan 169.02, which was approved on 13 July 1998 by the Chairman of the Animal Care and Use Committee at Northern Prairie Wildlife Research Center.

We used vehicles equipped with radio receivers to search the CPRV for radiomarked cranes each evening from mid-February to mid-April. Technicians searched the entire study area by scanning frequencies of all potentially active transmitters from roads parallel to the Platte River and from bridges crossing the river (Fig. 1).

We established eight roadside transects in the CPRV (Fig. 1; Krapu et al. 2005) and conducted ground surveys each week on Tuesdays beginning the third week of February and continuing through the second week of April 1998–2002 and 2009–2011. Each transect extended 16 km north and south from the main channel of the Platte River and was 400 m on each side of maintained roads (2,560 ha/transect; Fig. 1). Beginning at 0800 hours, field technicians drove the survey routes, enumerated cranes in each transect, and recorded their distances from the river channel. We calculated percentage of cranes observed on ground transects outside of the survey bounds used by the USFWS to conduct the aerial crane survey (Fig. 1) for each year.

Statistical Analysis

We inferred presence during periods from first to last detection of individual cranes and fit generalized linear random-effects models with a logit link to describe daily and annual variation in proportions of cranes that were present within the CPRV. We fit a model for each date from 20 February to 14 April. The response variable was a binomial variable identifying each crane as present or absent at the Platte River for that particular day of the year. Calendar year (2001–2007) was the random effect used in each model. We interpreted the back-transformed intercept as the expected proportion of cranes present and the random variance due to year as an estimate of annual variation. We used restricted maximum-likelihood estimation (PROC GLIMMIX; SAS Institute, Inc., Cary, NC) to fit models and the Delta method for back-transformations of the variance (Littell et al. 1996).

RESULTS

We marked 34 cranes with VHF transmitters during spring 2000, 34 in 2001, 34 in 2002, 101 in 2003, 87 in 2004, 100 in 2005, and 49 in 2006. We detected 305 cranes staging in the CPRV $\geq$1 spring migration after their year of marking. Our sample size of marked cranes detected staging in the CPRV varied from 16 in 2001 to 86 in 2006 (Table 1).

Percentages of marked cranes that were present on the scheduled survey date (fourth Tuesday of March) ranged from 71% (2007) to 94% (2001 and 2006; Table 1). The proportion of marked cranes that had not yet reached the

Table 1. Percentage of midcontinent sandhill cranes marked with VHF transmitters staging in Central Platte River Valley, Nebraska, USA, that were present, not yet arrived, or already departed the area during the scheduled survey date on the fourth Tuesday of March each year and during days of peak percentage present, 2001–2007.

		During scheduled survey				During yearly peak % present			
Year	*n*	Date	% Present	% Not arrived	% Departed	Dates	% Present	% Not arrived	% Departed
2001	16	27 Mar	94	6	0	30 Mar–3 Apr	100	0	0
2002	34	26 Mar	91	9	0	1–3 Apr	94	0	6
2003	24	25 Mar	75	17	8	30–31 Mar	79	8	13
2004	59	23 Mar	81	10	9	29–30 Mar	86	0	14
2005	42	22 Mar	88	10	2	24–26 Mar	93	2	5
2006	86	28 Mar	94	2	4	28–29 Mar	94	2	4
2007	44	27 Mar	71	2	27	13–15 Mar	77	23	0
$\bar{x}$[a]			86	7	7		90	5	5
SD[b]			7	6	3		6	4	4

[a] Mean estimated by intercept of random-effects linear model.
[b] Annual variation back-transformed using the Delta method.

CPRV by the scheduled survey date ranged from 2% (2006 and 2007) to 17% (2003), and 0% (2001 and 2002) to 27% (2007) of marked cranes departed before the survey date (Table 1 and Fig. 2). In all years except 2007, a greater proportion of cranes had yet to arrive at the Platte River than had departed prior to the survey date. On average, 86% of radiomarked cranes were present during the scheduled survey date and the standard deviation due to annual variation was 7%.

Population turnover was observed in all years except 2001, when all marked birds were present between 30 March and 3 April (Fig. 2). Annual timing of the peak percentage present occurred between 13 March and 3 April (Table 1), and the lowest peak presence occurred in 2007. Average peak presence was slightly greater than the average percentage present during the scheduled survey (90%) and variation was comparable (SD = 6%; Table 1). Averaged across all years, daily mean percentage of cranes present during 2001–2007 was greatest on 26 March (87%), and 22–26 March corresponded with the lowest estimated annual variation (SD = 6%; Fig. 3).

We tallied 12,000–40,000 cranes/survey during 24 roadside transect surveys conducted during the week preceding, week of, and week after scheduled crane surveys over an 8-year period (1998–2002 and 2009–2011). Zero to 11% of cranes were not within the established survey boundary during surveys conducted during the week of the scheduled crane survey ($\bar{x} = 3\%$; SD = 4%). A similar mean percentage of cranes (2%) was outside of the survey boundary during the week preceding scheduled surveys. A greater mean percentage (11%) was outside the surveyed area the week after the scheduled survey (Table 2).

DISCUSSION

Sandhill cranes congregate at the Platte River each spring for approximately 6 weeks to rest and acquire resources needed for continued migration and breeding (USFWS 1981, Krapu et al. 1985). This gathering of sandhill cranes has occurred for decades and is generally predictable (USFWS 1981), yet we found that arrival and departure periods of cranes varied annually in relation to the scheduled crane survey. Furthermore, the population experienced a period of turnover in most years, with some cranes arriving while others were departing. This variation in migration chronology may confound interpretations of natural population dynamics of cranes, adding uncertainty for both interpreting estimates from yearly sandhill crane surveys and for making management decisions based on survey results (Central Flyway Webless Migratory Game Bird Technical Committee 2006).

The crane survey has been scheduled at a time when, on average, the greatest percentage of the midcontinent population was present at the Platte River and annual variation was the least. In all years, we observed birds that had not yet arrived at the Platte River during the scheduled survey and, in most years, some birds had already departed. Overall, a similar number of cranes had not yet arrived and had already left the Platte River staging area during this time period. Thus, population turnover occurred in most years with certain cranes lagging behind and others leaving the Platte River ahead of the main group. We found that the lowest annual variation in cranes present at the Platte River generally corresponded with the standard practice of scheduling the survey on the fourth Tuesday in March. Conducting the survey considerably earlier than these dates would potentially miss birds that had not yet arrived. Surveying later would increase the chance of significant crane departure from the region and would occur at a time when considerable numbers of cranes might be using terrestrial habitats outside of the survey boundary.

Although of a lesser magnitude than annual variation in migration chronology, annual variation in cranes occurring outside of the survey boundary was apparent and may further compromise the relationship between survey estimates at the Platte River and true abundance of midcontinent cranes. Options to minimize this issue include expanding survey boundaries, which would require changes to the survey protocol and likely represent extra costs in flight time. Alternatively, experimental surveys using remote sensed imagery on roost sites nocturnally have shown promising results (Kinzel et al. 2006) and would greatly reduce this and other sources of variation (e.g., sampling error). Further

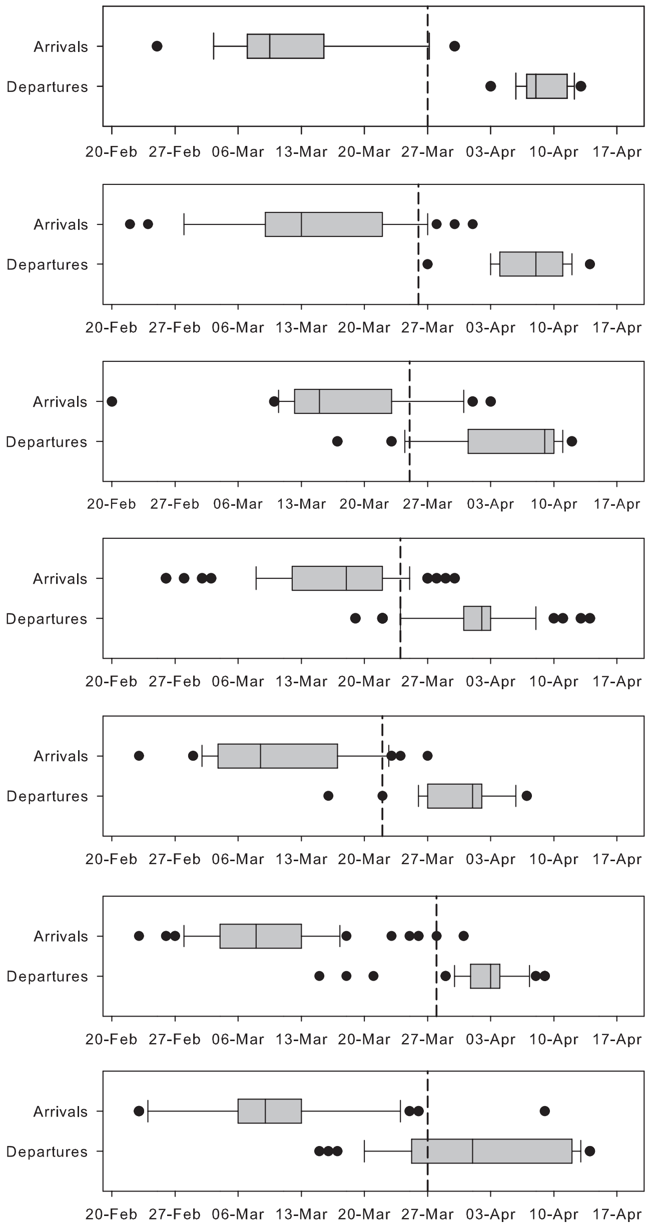

Figure 2. Yearly arrival and departure dates of sandhill cranes marked with VHF transmitters during spring (Feb–Apr), 2001–2007 at the Central Platte River Valley, Nebraska, USA. Gray boxes depict 25th, 50th, and 75th percentiles, whiskers illustrate 10th and 90th percentiles, and black circles represent data points outside of those percentiles. The dashed vertical line signifies the scheduled survey date.

technological advances in sensors, deployment vehicles, and processing software may increase effectiveness and reduce costs of these techniques, increasing the likelihood that they could be used in the operational survey (Jones et al. 2006).

Several authors have documented failure to detect migratory birds immediately upon arrival at, or immediately prior to departure from, staging areas (e.g., Schaub et al. 2001, Cohen et al. 2009). Although departure was the most likely cause when we lost radio contact, other causes (e.g., destruction or failure of radios) also were possible. Whereas such errors have implications for estimation of

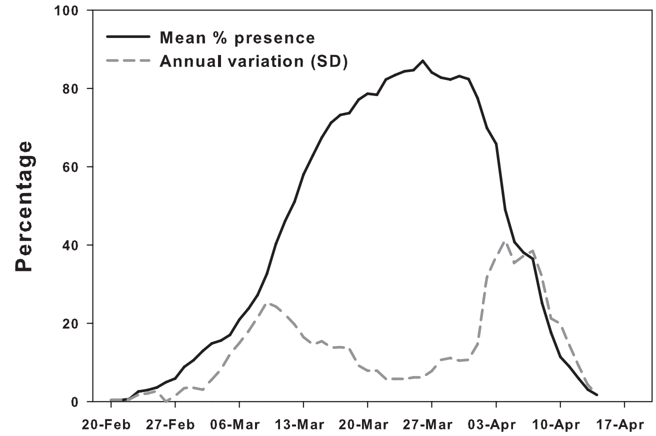

Figure 3. Mean percentage and annual variation of sandhill cranes marked with VHF transmitters present within the Central Platte River Valley, Nebraska, USA, during spring migration (Feb–Apr), 2001–2007.

Table 2. Percentage of midcontinent sandhill cranes observed during ground counts outside of the survey boundary used in the U.S. Fish and Wildlife Service coordinated crane survey along the Central Platte River, Nebraska, USA, the week preceding, week of, and week after the scheduled survey, 1998–2002 and 2009–2011.

Year	Pre-survey	During survey	Post-survey
1998	<1	0	3
1999	10	6	15
2000	3	11	23
2001	<1	4	25
2002	0	<1	8
2009	<1	5	8
2010	0	0	0
2011	<1	<1	7
$\bar{x}$	2	3	11
SD	4	4	9

arrival dates, departure dates, and residency times, estimates of interim presence during staging were much more robust, requiring just one detection on or before, and one detection on or after, a survey date. Because detection rates were high (approx. 0.78, [95% Bayesian credible interval = 0.77–0.79]; G.A. Sargeant, unpublished data) and few cranes were first or last observed immediately prior to survey dates, observed proportions closely approximated actual proportions of cranes present on survey dates.

Our 7-year study of migration chronology represents current best available data, but we recognize certain limitations. In some years, we had relatively small sample sizes of marked cranes, which increased uncertainty in annual estimates. Also, our estimates of crane presence in the region were applicable only to the CPRV and not to the NPRV, where approximately 15–20% of cranes stage each spring (Krapu et al. 2014). North Platte River Valley birds likely have a more synchronous and later departure schedule than CPRV birds in general (Krapu et al. 2014); therefore, additional data collection of NPRV cranes would allow for an improved evaluation of the crane survey. More importantly, the 7 years of data we collected are not sufficient to reliably characterize temporal variation that exists in the migration chronology for this population. We consider estimates provided in this study as provisional if they were to be used as a correction factor for the spring crane survey (e.g., Cohen et al. 2009). Additional monitoring of a sample of midcontinent sandhill cranes would increase reliability of the spring survey to detect trends in this population as well as provide further data to update our provisional estimates of annual variation in sandhill crane presence at the Platte River during spring. Our estimates would provide excellent prior information that could be updated with additional years of data collection in conjunction with future crane surveys in a Bayesian analysis framework (e.g., Johnson 1989). This effort could be extended to include predictor variables that may allow development of a model to predict migration chronology. Such an effort would be useful for resource managers that desire an understanding of how long-term changes in climate and land use influence crane migration and population dynamics.

MANAGEMENT IMPLICATIONS

Observed annual variation in presence of midcontinent sandhill cranes during late March in the CPRV represents a challenge in interpreting population dynamics based on the current survey methodology. Our results suggest that late March continues to be the most appropriate time to survey cranes at the Platte River because it generally reflects times of greatest percentage of cranes present with lowest annual variation. During years when the fourth Tuesday in March occurs outside of 22–26 March, some consideration could be given to changing the survey date to correspond with this timing. Even with minor scheduling changes, crane managers should be aware that significant uncontrolled variation due to migration chronology and spatial distribution exists, which compromises interpretation of population dynamics of the midcontinent sandhill crane population.

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